Superconducting Magnet Design for the eRHIC Detector

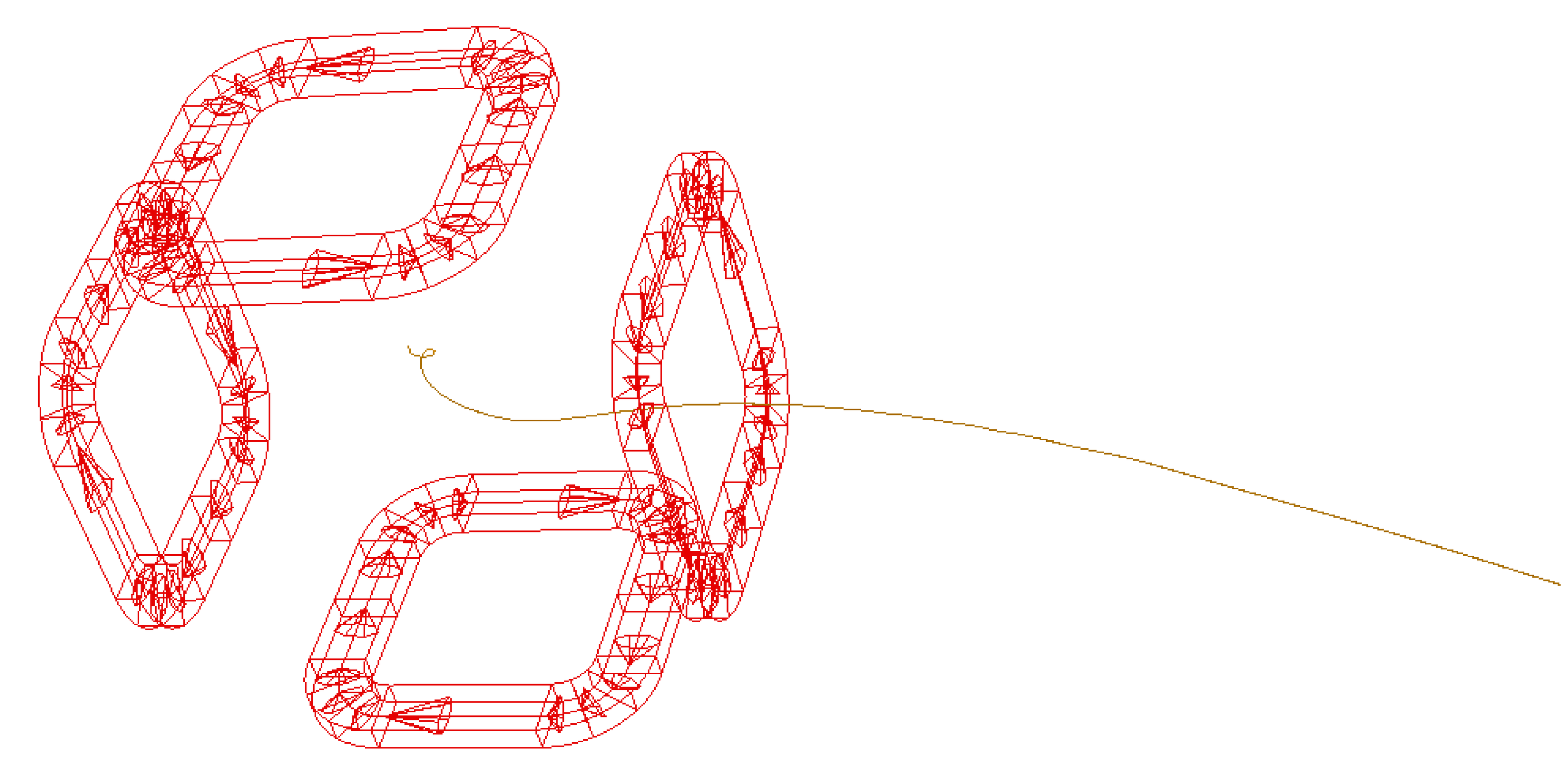
Richard E. Darienzo[1], Eric Fackelman[2], Elke-Caroline Aschenauer[1] , Brett Parker[1]
[1]Physics Department, Brookhaven National Laboratory, Upton, New York 11973
[2]SUNY at Stony Brook, Stony Brook, New York 11790

Abstract

The proposal to add an electron beam to the Relativistic Heavy Ion Collider (eRHIC) at Brookhaven National Laboratory (BNL) is part of a worldwide collaboration to realize an Electron-Ion Collider (EIC). The EIC will allow physicists to gain new insight into gluons, the force carriers of the strong interaction.

As in any particle detector, super conducting magnets are used to apply large magnetic fields to not only guide beams of particles but to bend the debris of particles resulting from a collision of two beams. The ideal magnet will allow for high resolution of each particle's momentum and adequate spacing for the mounting of various particle detectors.

We investigated possible magnet (conductor) designs that would be the ideal synthesis of functionality and plausibility using OPERA-3d electromagnetic analysis software.



OPERA-3d allows the user full control over the size and shape of a magnet model. It can also simulate the effects of the magnets on a charged particle. Above is a model of four "racetrack" conductors, with current flow indicated by the red arrows. The spiraling yellow line is the trajectory of an electron with a total energy of 5 GeV.

The Design Process

Understand the Experiment

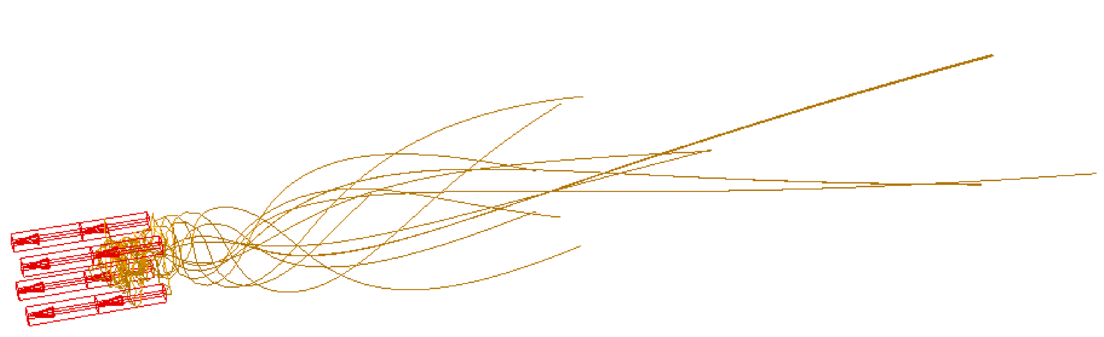
The ideal magnet for the eRHIC project would have a strong radial field (pointing away from the central axis in all directions) present over a large volume. This is necessary because the eRHIC experiments involve an electron hitting either protons or ions. These collisions produce hadrons (e.g., protons, kaons) and leptons (e.g., electrons, positrons). The most interesting leptons produced scatter through a small angle close to the beam axis, which the magnet must bend toward the detectors.

Model the Magnets

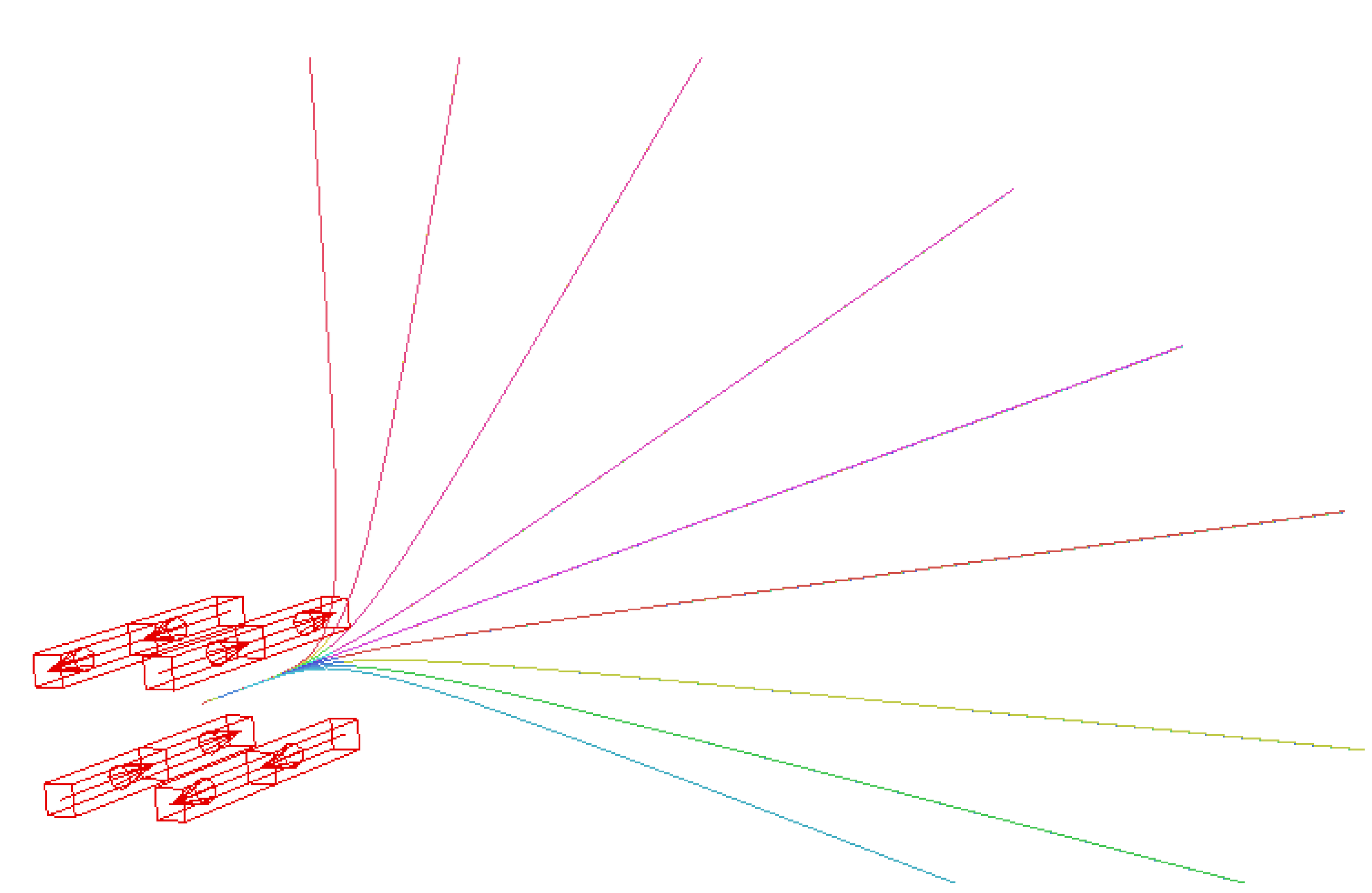
Using OPERA-3d software, different magnets are created. These magnets then have their geometries, current densities and orientation manipulated to create the desired magnetic field. OPERA-3d has the ability to use pre-programmed conductors, such as solenoids, as well as user defined geometries. Various geometries can be created by manipulating 8- or 20-node bricks, which can then be translated and copied to produce more complicated conductors.

Run Simulations

Even the most carefully designed conductor might not produce the desired magnetic field. OPERA-3d allows the user to see a conductor's magnetic field strength and direction. In addition, particles of different mass and charge can be placed in any region near the conductor with almost any energy. This allows designers the ability to test how well their magnet design deflects particles toward detectors. This step determines the functionality and plausibility of a design.



Simulations of the magnetic field and how it effects particle trajectories is critical for the viability of a design. The above image shows four conductors in red and particle trajectories in yellow. This design failed to meet experiment specifications due to the spiraling particle trajectories.



Using the tools provided by OPERA-3d, failed designs can become successful ones. The image to the left is the result of careful modification to the current magnitude and direction in the four red conductors. The rainbow of lines emanating from the center of the conductors traces the simulated trajectories of electrons, each with an energy of 5 GeV.

BROOKHAVEN NATIONAL LABORATORY

Stony Brook University

Office of Science U.S. DEPARTMENT OF ENERGY

U.S. DEPARTMENT OF ENERGY

Acknowledgements

Special thanks to all of those who not only made this project possible but also provided guidance and wisdom:
Elke-Caroline Aschenauer
Brett Parker
Tom Hemmick
The OEP Team